Reverse total shoulder arthroplasty for acute head-splitting, 3- and 4-part fractures of the proximal humerus in the elderly

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Abstract: Due to the aging population with poor bone quality the frequency of complex proximal humerus fractures increases. An operative reconstruction and internal fixation is very challenging and is not always possible. Secondary impaction, screw perforations and humeral head necrosis is a common complication. The use of a Reverse Total Shoulder Arthroplasty in the elderly after trauma is a promising alternative. The present multicenter study retrospectively analyzes our long-term experience of reverse total shoulder arthroplasty as a primary treatment in this patient population regarding pain, range of shoulder motion, subjective shoulder value, the constant score, scapular notiching and signs of loosening.

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ORIGINAL ARTICLE

Reverse total shoulder arthroplasty for acute head-splitting, 3- and 4-part fractures of the proximal humerus in the elderly

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Background: Anatomic reduction and stable internal fixation of complex proximal humeral fractures in the elderly is challenging. Secondary displacement, screw perforation, and humeral head necrosis are common complications. The outcome of hemiarthroplasty is unpredictable and strongly dependent on the uncertain healing of the greater tuberosity. This multicenter study retrospectively analyzes the midterm results of primary reverse total shoulder arthroplasty for the treatment of acute, complex fractures of the humerus in an elderly population.

Methods: Fifty-two shoulders in 51 patients with a mean age of 77 years treated with reverse total shoulder arthroplasty for an acute, complex fracture of the proximal humerus were clinically and radiographically analyzed after a mean follow-up period of 35 months (range, 12-90 months).

Results: There were no intraoperative complications. Revision surgery was performed in 4 shoulders. At final follow-up, the absolute and relative Constant scores averaged 62 points (range, 21-83 points) and 86% (range, 30%-100%), respectively, with a mean Subjective Shoulder Value of 83% (range, 30%-100%). Of the patients, 92% rated the treatment outcome as excellent or good. Patients with a resected or secondarily displaced greater tuberosity had an inferior clinical outcome to those with a healed greater tuberosity.

Conclusion: The midterm clinical results are predictably good, with low complication rates and a rapid postoperative recovery of painfree everyday function. If secondary displacement of the greater tuberosity occurs, revision surgery may warrant consideration in view of potential improvement of ultimate outcome.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Complex proximal humeral fracture; reverse total shoulder arthroplasty; greater tuberosity healing; greater tuberosity displacement; elderly patients; greater tuberosity resection

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained. The study was approved by the Ethical Committee Zurich (Cantonal Ethical Committee No. KEK-ZH-Nr.2015-0004).

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Whereas the nondisplaced 80% of proximal humeral fractures are well treated conservatively, unstable, displaced 2-, 3-, or 4-part fractures especially in elderly patients with osteoporotic bone, as suggested by Baron et al,[2] would benefit from satisfactory surgical treatment.[34] There is no general agreement on the optimal treatment for these fractures, and 1 of 9 patients treated with open reduction–internal fixation (ORIF) or hemiarthroplasty requires revision surgery[21] because of often serious complications.[6,9,25,29,37,41,45]

An acceptable solution should take the osteoporotic bone especially of the greater tuberosity into account and ensure a predictable and rapid postoperative recovery of the ability to perform daily activities, independent of patient compliance and capability of postoperative rehabilitation. The use of a reverse total shoulder replacement (reverse total shoulder arthroplasty [RTSA]) as proposed by Grammont et al[19] is an alternative that addresses the additional fragility of the rotator cuff and has shown promising results in a few case series.[4,7-9,11,12,24,26,32,40] It appears established that reattachment of the greater tuberosity yields a better functional outcome than resection of the greater tuberosity.

The purpose of this multicenter study is to retrospectively analyze our short-term to midterm results of RTSA with reattachment of the tuberosities as a primary treatment for elderly patients with complex fractures of the proximal humerus. We assume that RTSA for complex proximal humeral fractures yields a more reliable and more predictable outcome with a lower complication rate than hemiarthroplasty. We also hypothesize that patients with greater tuberosity healing after RTSA without secondary displacement show better results than patients without greater tuberosity healing.

Methods

The study was performed in 2 orthopedic hospitals (Balgrist University Hospital, University of Zurich, Zurich, Switzerland, and Department of Orthopaedics and Traumatology, Bürgerspital Solothurn, Solothurn, Switzerland). We retrospectively reviewed all patients identified in our comprehensive database who had undergone RTSA for head-splitting, 3-part, or 4-part fractures of the proximal humerus between October 2005 and October 2013.

We identified 73 patients (8 men and 65 women). Of these, 34 were treated at Balgrist University Hospital and 39 at the Department of Orthopaedics and Traumatology, Bürgerspital Solothurn. Fifty-one patients (6 men and 45 women) with a mean age of 77 years (range, 58-89 years), with 52 treated shoulders (32 right and 20 left), were available for follow-up at a mean of 35 months, with a minimum follow-up of 12 months (range, 12-90 months).

We identified 10 head-splitting fractures, 4 three-part fractures, and 38 four-part fractures. All were reviewed clinically, including scoring according to Constant and Murley,[10] as well as radiographically. Two patients with a postoperative infection that occurred 4 months after RTSA (in both) needed surgical revision with a temporary spacer implantation and were excluded from functional assessment (Table I).

Table I Patient demographic data

Variable	Data
Total No. of patients identified	73
Number of patients included	51 (with 52 RTSAs [1 bilateral fracture])
Indication for RTSA, n	
Head-splitting fracture	10
Three-part fracture	4
Four-part fracture	38
Follow-up after RTSA, mean (range), mo	35 (12-90)
Delay from fracture to RTSA, mean (range), d	5 (0-16)
Gender, n	
Male	6
Female	45
Age at RTSA, mean (range), y	77 (58-89)
Surgical site, n	
Right	31
Left	13
Revision surgery, n	4
Periprosthetic humeral fracture (2 y after RTSA)	1
Postoperative hematoma	1
Infections—excluded from analysis because of RTSA explantation (ie, dropout)	2
Lost to follow-up, n	20
Died without undergoing follow-up examination	14
Refused follow-up examination because of age and general health status	6

Patients underwent RTSA for proximal humeral fractures between October 2005 and October 2013 at the Department of Orthopaedics and Traumatology, Bürgerspital Solothurn, or at Balgrist University Hospital.
RTSA, reverse total shoulder arthroplasty.

Dropout patients

Twenty patients were lost to follow-up. Four patients (aged 73-96 years at the time of surgery) died within the first year (range, 4 days to 9 months) without any direct relation to the fracture or the operative procedure. Ten further patients (aged 69-91 years at the time of surgery) died at a mean of 30 months (range, 13-62 months) after surgery without having undergone any postoperative annual follow-up visits and therefore could not be included in the study.

Five patients (aged between 81 and 89 years) lived in nursing homes and were contacted by telephone between 3 and 4 years after RTSA. All judged their result as excellent; they were free of pain with a Subjective Shoulder Value (SSV) between 60% and 100% but refused further follow-up ap-

pointments because of a poor general health status. One 80-year-old woman had moved to another country and had no follow-up visits at our institutions. She was contacted by telephone and rated her SSV as 100% and the result as very good.

Surgical technique

All procedures were performed using the Zimmer Reverse Anatomical Shoulder System (Zimmer, Warsaw, IN, USA). A fracture stem was used in all cases. The mean delay from injury to surgery was 5 days (range, 0-16 days). The fracture was exposed, and the tuberosities were mobilized and grasped with No. 5 FiberWire sutures (Arthrex, Naples, FL, USA). After removal of the head fragments, the glenoid was minimally reamed to conserve as much subchondral bone as possible. The height of the prosthetic stem was determined using the following references with the knowledge that this prosthetic system requires introduction of the shaft to the same level, whether an anatomic or a reverse system is used: (1) the distance from the upper border of the pectoralis major tendon to the prosthetic head[33]; (2) the distance from the tip of the fractured greater tuberosity to the articular-side insertion of the rotator cuff, which determines the height of the lateral aspect of the humeral head; and (3) the height of the cartilage-free zone of the humeral head at the calcar, which determines the medial-inferior border of the prosthetic head.[13] The decision to cement the stem was made intraoperatively depending on bone quality to press fit with the largest possible stem. The stem was implanted at between 0° and 20° of retroversion to avoid tension on the greater tuberosity during internal rotation. Finally, the greater tuberosity was reattached if possible in the anatomic position to the prosthesis and in a transosseous manner to the humeral metaphysis with No. 5 FiberWire. In 4 earlier cases, the greater tuberosity was so thin that no hold of the sutures could be obtained, so the remaining greater tuberosity was resected.

Postoperative aftercare included 2 suction drains for 48 hours and a sling for a maximum of 6 weeks. All patients were treated with passive external and internal rotation and active-assisted elevation exercises for 6 weeks. Everyday activities were allowed, avoiding weight bearing.

Assessment

The Constant score (CS),[10] SSV,[14,18] age- and gender-matched relative CS,[17] pain level, and patient's outcome satisfaction were recorded as the primary endpoints. Range of motion, position of the greater tuberosity, inferior scapular notching, and signs of loosening were assessed as secondary endpoints. The patient satisfaction rate was assessed by asking patients to define their overall satisfaction with the treatment result. The possible answers were "excellent," "good," "fair," and "unsatisfactory." The assessment was entirely subjective. The investigator instructed the patients that they only needed to judge the state of the shoulder.

During follow-up, including the last visit, implant position, inferior scapular notching, signs of loosening, and greater tuberosity position were analyzed radiographically on standardized anteroposterior, axillary lateral, and scapular lateral radiographs. Scapular notching was assessed according to Sirveaux et al.[42] Humeral loosening was assessed with the method described by Sperling et al.[43]

Statistical analysis

Study data were collected and managed using the REDCap electronic data capture tool,[22] version 6.7.4 (Vanderbilt University, Nashville, TN, USA), hosted at Balgrist University Hospital. For statistical analysis of the CS and SSV endpoints, the nonparametric Wilcoxon signed rank test was used to compare 2 groups: patients with healed greater tuberosities and patients with unhealed greater tuberosities. A P value $< .05$ was considered significant.

Results

After a mean of 35 months (range, 12-90 months), 35 patients rated their postoperative result as excellent, 13 as good, and 4 as fair. None of the patients was dissatisfied. The absolute CS averaged 62 points (range, 21-83 points), and the relative CS averaged 86% (range, 30%-100%). The pain level, as measured with the CS, which assigns values from 0 points (most severe pain) to 15 points (no pain), averaged 14 points (range, 5-15 points). The SSV averaged 83% (range, 30%-100%). Mean active anterior elevation was 118° (range, 40°-165°), mean active abduction was 111° (range, 40°-165°), and mean active external rotation in 0° of abduction was 18° (range, 0°-65°). Mean active internal rotation with the hand behind the back (as measured with the CS) was 5 points (range, 0-10 points), and the mean value for activities of daily living using the CS was 9 points (range, 0-10 points).

Of the 51 patients, 4 rated their treatment outcome as fair. In 2 of them (female patients aged 83 years and 74 years), the greater tuberosity had been resected. The third patient with a subjectively fair result was a 76-year-old woman who had progressive rheumatoid arthritis. The fourth patient with a fair result was a 74-year-old woman who preoperatively had a left-sided hemiplegia after a cerebrovascular accident (Table II). The results in both centers did not differ significantly with the exception of active shoulder abduction.

Radiographic findings

Overall, no radiographic signs of loosening were detected, either on the baseplate or on the stem. Inferior scapular notching was seen in 33 cases (63%). According to the classification of Sirveaux et al,[42] grade 4 scapular notching was present in 4 cases, grade 3 in 2 cases, grade 2 in 9 cases, and grade 1

Table II Overall clinical results

	Data
CS, points	62 (21-83)
Relative CS, %	86 (30-100)
SSV, %	83 (30-100)
Flexion, °	118 (40-165)
Abduction, °	111 (40-165)
External rotation, °	18 (0-65)
Internal rotation, points (in CS)	5 (0-10)
ADLs, points (in CS)	9 (0-10)
VAS, points (in CS)	14 (5-15)
Satisfaction	93% high satisfaction
Excellent	35 RTSAs
Good	13 RTSAs
Fair	4 RTSAs
Dissatisfied	0 RTSAs

ADLs, activities of daily living; *CS*, Constant score; *RTSA*, reverse total shoulder arthroplasty; *SSV*, Subjective Shoulder Value; *VAS*, visual analog scale.
Data are presented as mean (range) unless otherwise noted.

in 18 cases. There was no correlation of outcome with degree of notching.

Forty-four patients had no signs of secondary displacement of the greater tuberosity and were considered to have a radiographically healed greater tuberosity (Fig. 1). Four patients showed secondary greater tuberosity displacement (Fig. 2), and in 4 patients, the greater tuberosity had been resected during surgery because of pluri-fragmentation. These 8 patients with secondarily displaced or resected greater tuberosities had significantly lower CS, with a mean of 50 points (range, 21-66 points), compared with the patients with healed greater tuberosities, who had a mean CS of 65 points (range, 53-83 points) (Table III, Figs. 3 and 4). The SSV of the patients with healed greater tuberosities was significantly higher than that of the 8 patients without greater tuberosity healing (89% [range, 43%-100%] vs 72% [range, 30%-100%]) (Fig. 5). Range of motion and ratings of activities of daily living were also better in the group of patients with healed greater tuberosities (Table III).

Of the 44 patients with radiographically healed tuberosities, 5 showed radiographic evidence of greater tuberosity healing at 6 weeks but some osseous resorption of the greater tuberosity at the final follow-up. These patients showed no outcome differences compared with the patients with healed, non-resorbed greater tuberosities.

Complications

In the complete study population of 73 patients with 74 RTSAs, we had a revision surgery rate of 5% (4 revision surgical procedures out of 74 RTSAs). One 80-year-old female patient needed revision surgery because of a postoperative hematoma. At the last follow-up examination 2 years after

Figure 1 A female patient (aged 83 years) with a 4-part fracture with a reattached and healed greater tuberosity after reverse total shoulder arthroplasty. The first row shows radiographs obtained preoperatively; second row, immediately postoperatively; third row, 6 weeks postoperatively; and fourth row, 2 years postoperatively.

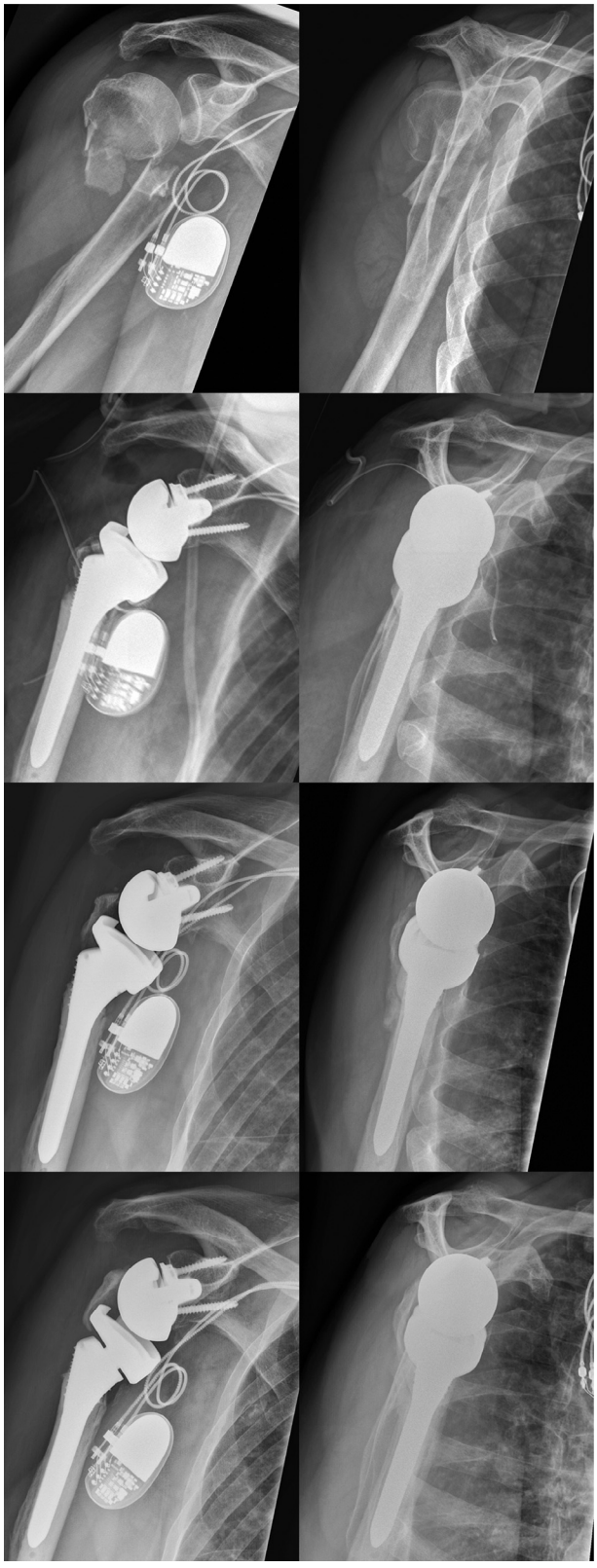

Figure 2 A male patient (aged 64 years) with secondary displacement of the primarily reattached greater tuberosity after reverse total shoulder arthroplasty. The first row shows radiographs obtained preoperatively; second row, immediately postoperatively; third row, 6 weeks postoperatively; and fourth row, 2 years postoperatively.

surgery, she assessed the treatment outcome as good, with an absolute CS of 66 points and an SSV of 70%.

Another patient, a 83-year-old woman, sustained a traumatic periprosthetic humeral shaft fracture 2 years after RTSA during a fall. This was treated with a long fracture stem. Three years after revision surgery, the patient had an absolute CS of 42 points. She reported having almost no pain (visual analog scale score of 14) and rated the SSV of her operated dominant right shoulder as 60%.

An 81-year-old female patient was identified to have coagulase-negative staphylococci infection 4 months after RTSA. Obesity and insulin-dependent diabetes were her risk factors. She was treated by a 2-stage revision with debridement and interim cement spacer implantation and, finally, by revision RTSA. Two years after revision RTSA, she had an absolute CS of 74 points, was pain free, and was very satisfied with the result.

In a second patient, a 68-year-old woman, infection with *Propionibacterium* developed, also 4 months after the index procedure. She underwent a 2-stage revision with interim cement spacer implantation, and revision RTSA combined with a latissimus dorsi tendon transfer was successfully performed 13 months after spacer implantation. Two years after revision RTSA, the patient was free of pain and was satisfied with her shoulder; the CS was not assessed.

Finally, a 73-year-old female patient who had a known aortic stenosis died of acute coronary syndrome 4 days after an uneventful operative intervention. Intraoperative glenoid fracture, dislocation, aseptic loosening of implant components, acromion fracture, neurologic complications, complex regional pain syndrome, and deep venous thrombosis were not reported either at the follow-up visits or in the medical records of the dropout patients.

Discussion

Head-splitting, 3-part, and 4-part fractures of the proximal humerus in the elderly pose various challenges because of poor bone quality and difficult aftercare due to poor compliance. ORIF using conventional or locking plates is preferred in young patients with good or excellent bone quality. However, complication rates of up to 35%[6,44] in osteoporotic bone, due to secondary displacement, screw perforation, and humeral head necrosis, raise concern. In our cohort, the indication for arthroplasty was the biological age of the patient in addition to the complexity of the fracture. For this reason, one 58-year-old female patient with metastatic melanoma was treated with RTSA.

We defined head-splitting fractures and 3- and 4-part fractures of the proximal humerus as complex fractures. Shoulder hemiarthroplasty might be considered an alternative with satisfactory pain relief in 60% to 90% of patients. Nonunion, malunion, and resorption or migration of the greater tuberosity are the most common complications and ultimately lead to inconsistent and mainly disappointing functional

Table III Clinical results in patients with healed versus displaced or resected greater tuberosities

	Healed tuberosities (n = 44)	Displaced or resected tuberosities (n = 8)	*P* value
CS, points	65 (33 to 83)	50 (21 to 65)	.01
SSV, %	86 (30 to 100)	68 (45 to 100)	.03
VAS, points (in CS)	13.8 (8 to 15)	12.7 (5 to 15)	NS (.21)
ROM			
AAE, °	123 (45 to 165)	94 (40 to 130)	.01
AAB, °	115 (40 to 165)	92 (40 to 140)	NS (.11)
AER, °	21 (−10 to 60)	2 (0 to 10)	.01
AIR, points (in CS)	6 (0 to 10)	3 (0 to 8)	NS (.06)
ADLs, points (in CS)	7 (0 to 10)	9 (0 to 10)	.01

AAB, active abduction; *AAE*, active anterior elevation; *ADLs*, activities of daily living; *AER*, active external rotation; *AIR*, active internal rotation; *CS*, Constant score; *NS*, not statistically significant; *ROM*, range of motion; *SSV*, Subjective Shoulder Value; *VAS*, visual analog scale.
Data are presented as mean (range).

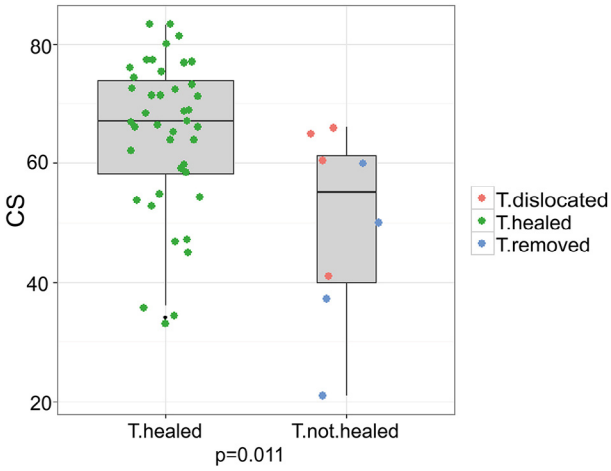

Figure 3 Constant score (CS) in patients with healed greater tuberosities (T healed) versus patients with resected or secondarily displaced greater tuberosities (T not healed). The difference between the 2 groups was statistically significant ($P = .01$): 65 points (range, 53-83 points) versus 50 points (range, 21-66 points).

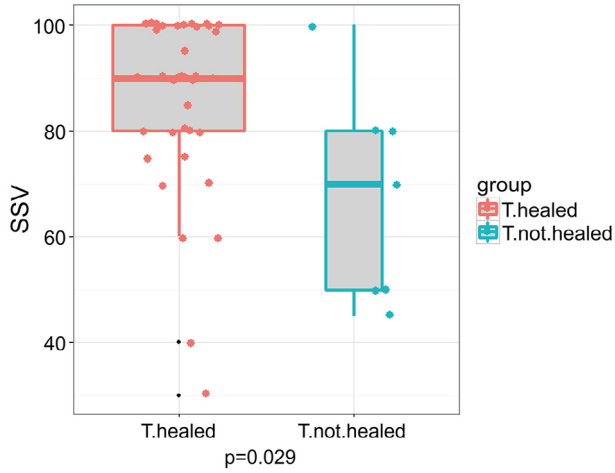

Figure 4 Subjective Shoulder Value (SSV) in patients with healed greater tuberosities (T healed) versus patients with resected or secondarily displaced greater tuberosities (T not healed). The difference between the 2 groups was statistically significant ($P = .03$): 89% (range, 43%-100%) versus 72% (range, 30%-100%).

results.[1,3,5,12,16,23,28] Therefore, a current trend from hemiarthroplasty toward RTSA is reported for complex humeral fractures in the elderly.[38]

RTSA yields better functional outcomes and a lower complication rate than hemiarthroplasty in the treatment of complex fractures of the proximal humerus in the elderly. Furthermore, failed hemiarthroplasties can successfully be revised with RTSA.[35,46]

The primary use of RTSA for acute fractures has been reported in several small single-center series.[4,7,8,11,24,26,39,40,42] Our series reports the outcomes from 2 independent centers using the same implant and technique. We did not find any differences in the primary outcome endpoints of the patients at one center versus the other, so the results were reproducible.

The main limiting factor of our investigation is the dropout rate (20 of 73 patients); this, however, is mainly related to the patients' advanced age at the time of surgery and, therefore, reduced general health status and consequently high mortality rate (14 of 73). In addition, such patients may refuse a personal follow-up visit, which was the case in 6 patients in our series, mainly because of immobility, dementia, or having moved too far away. To reduce the outcome uncertainty of the dropout patients, we—together with the patients' treating and/or referring physicians—reviewed all medical records of the 14 deceased patients. In addition, family members were asked whether any further shoulder surgery was necessary or whether the patient had had shoulder pain. No revision surgical procedures could be found in the medical

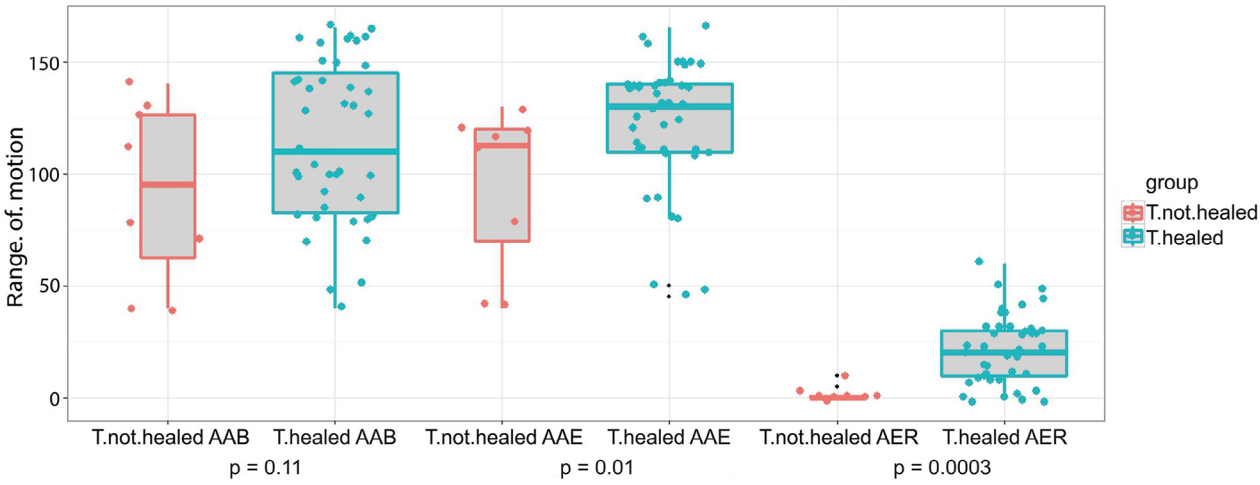

Figure 5 Range of motion (in degrees) in patients with healed greater tuberosities (T healed, n = 44) versus patients with resected or secondarily displaced greater tuberosities (T not healed, n = 8). The difference between the 2 groups was statistically significant for active anterior elevation (AAE) ($P = .01$), 123° (range, 45° to 165°) versus 94° (range, 40° to 130°), and for active external rotation (AER) ($P = .01$), 21° (range, –10° to 60°) versus 2° (range, 0° to 10°). The difference was not statistically significant for active abduction (AAB) ($P = .11$), 115° (range, 40° to 165°) versus 92° (range, 40° to 140°), or for active internal rotation ($P = .06$) (not shown).

records. Nine patients reported no shoulder pain and a subjectively good result. Five patients complained of some discomfort in the operated shoulder and problems with range of motion during their last recorded doctor's visit. All 6 patients who refused to come to the hospital could be interviewed by telephone and had no pain and subjectively good results, so revision or an unsatisfactory result could be excluded. The patients' ages explain the rather short average follow-up period of 35 months, as well as the decision to include patients (n = 7) with a follow-up period of less than 24 months albeit more than 12 months.

In this series, we found a very high subjective satisfaction rate, with 92% of patients (48 of 52) rating their subjective satisfaction as good or very good, with a mean SSV of 83% and relative CS of 87%, which compares favorably with published data.[4,7,8,16,26,32] The revision rate of 5% (4 of 74 RTSAs) is relatively low compared with other series, and only 3% of shoulders (2 of 74 RTSAs) needed temporary removal of the prosthesis because of infection.

According to a systematic review of 92 studies including 4500 patients with proximal humeral fractures, the complication rates for ORIF are approximately 15% for closed reduction, 28% for closed reduction and percutaneous pinning, 11% for hemiarthroplasty, and 18% for RTSA.[20] The revision rates are approximately 13% for ORIF, 10% for closed reduction and percutaneous pinning, 5% for hemiarthroplasty, and 5% for RTSA.

The death of the 73-year-old woman 4 days after RTSA in our study has to be reported as an acute postoperative death. However, a direct correlation with the uneventful RTSA procedure could not be found in the medical record.

Inferior scapular notching is a common finding in RTSA. Lévigne et al[30] reported a rate of 68% in their series. Our study shows comparable results, with notching in 63% of cases. Although the study population is too small to perform statistical analysis of correlations between notching grade and functional and subjective outcome, 3 of the 4 patients with grade 4 notching had an absolute CS below 50 points.

We tried to reattach the greater tuberosity and can confirm that the results with reattached and healed greater tuberosities are better than those with resected or secondarily displaced greater tuberosities,[8,15,27,31,36] so a major effort to reattach the greater tuberosity seems clearly justified. Compared with hemiarthroplasty, in which nonunion or displacement of the greater tuberosity has been reported to occur at a rate of 20% to 50%,[12] tuberosity nonunion or displacement of the greater tuberosity occurred in only 9%. This finding may be explained by the medialization of the center of rotation with lower tension on the tuberosities. Despite the high rate of radiologically healed tuberosities, mean active external rotation was only 18° in the whole cohort and 21° in patients with healed tuberosities. This finding may reflect that the supraspinatus and infraspinatus muscles are not normal at the respective age and after fracture. On the other hand, the ability to perform active external rotation was significantly better in patients with healed tuberosities (21°) than in patients with no healing or with resection of the tuberosity (2°). It may be criticized that healing of the greater tuberosity and rotator cuff would be more precisely assessed using computed tomography scanning, but with the serial radiographs, which were always taken in standardized positions, the readout of the radiographs was unequivocal. Although the study size is too small to justify a change in current treatment concepts, we think that revision surgery has to be considered in cases of secondary greater tuberosity displacement after RTSA because of the impaired subjective and objective outcomes that are to be expected if the displacement is accepted. We do

acknowledge, however, that we have not yet shown that secondary reattachment is consistently successful.

Conclusion

RTSA for acute head-splitting, 3-part, and 4-part fractures of the proximal humerus in elderly patients with osteoporotic bone yielded very satisfactory subjective and objective outcomes with acceptable complication and revision rates in our study population. In case of secondary displacement of the greater tuberosity after RTSA, revision surgery may need to be considered because of the otherwise definitely impaired functional outcome.

Disclaimer

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